

Research Models with Dissemination Activities for Research Experience for Teachers (RET)

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Abstract— Faculty members and staff from the Schools of Engineering & Technology, Science, and Education at Indiana University-Purdue University Indianapolis (IUPUI), have developed a model to provide research experience for high school teachers. In this intensive 8 week program, teachers spend 6 weeks in the summer conducting research, and two weeks designing classroom modules based upon their research experience to implement during the academic year.

Keywords—*nanotechnology education; teacher professional development; tactics; incidental learning*

I. INTRODUCTION

Research Experiences for Teacher Advancement In Nanotechnology (RETAIN) is a teacher professional development program that integrates the multidisciplinary components of STEM to enhance instructional skillsets amongst secondary teachers. The emerging field of nanotechnology and its collaborative nature provides a platform to impact teachers across STEM disciplines and the ‘wow-factor’ needed to boost student interest. This program’s focus on nanotechnology research in bionanotechnology and renewable energy applications are concentrations that maximize campus strengths (e.g., the Lugar Center for Renewable Energy and the IU School of Medicine) and meet both national and local demands (e.g., Eli Lilly, Cummins, Enerdel, Roche) for nanotechnology-literate STEM-field graduates. Despite high local demand, local student statistics, in respect to STEM disciplines, are surprising low and RETAIN is attempting to overturn these patterns through the creation of 15 nanotechnology-focused teaching modules (5/yr) developed in alignment with state standards and designed to build student interest in STEM fields, increase interest and understanding of STEM careers, and inspire continued education. Aside from the program’s thematic uniqueness and ability to successfully reach underrepresented student populations, RETAIN’s expansive professional development and graduate credit components are designed to train teachers on inquiry-based pedagogy, how to create and integrate new teaching modules that align with state standards, and on how to assess the impact of new modules on students. The skillset fostered through RETAIN not only pertains to nanotechnology, but can be incorporated throughout participants’ educational careers. By providing educational and technological professional development, alongside training in the basics of teaching module assessment and data collection, RETAIN provides teachers the opportunity to continue to advance and update their curriculum to the betterment of students.

The purpose of this paper is to first fully describe the RETAIN intervention and then to explore and discuss the preliminary results and initial lessons learned related to the first year of RETAIN. These results identify positive, direct and incidental outcomes, as well as areas in need of improvement. We conclude with discussing the implications of these findings and how particular refinements can enhance this and similar programs.

II. PROGRAMATIC APPROACH

A. The RETAIN Program

RETAIN is an immersive research education program for high school teachers. It provides educators with research experiences coupled with substantial professional development components and coursework for graduate credits. Inquiry has been indicated to be a vital piece in high quality, student-centered STEM education [1,2]. Program activities were specifically designed to train teachers on inquiry-based learning [3,4] and translating their research experiences into refined classroom teaching modules, as guided by the Science Teacher Inquiry Rubric (STIR) [5] designed to boost STEM interest and encourage high school students to pursue higher education and future careers in STEM-fields. Teachers from all STEM disciplines are able to participate within the multidisciplinary field of nanotechnology. In addition to a resume and letter of support from their school principal, applicants were selected based on their training and educational background and how they expect the professional development and research experiences of RETAIN will benefit them. IUPUI’s urban location provides the context for the program, while the partnership between its Integrated Nanotechnology Development Institute (INDI), its Center for Research and Learning (CRL), and its STEM Education Innovation and Research Institute (SEIRI) provides the infrastructure for supporting summer researchers and offers an excellent foundation to RET site dedicated to advancing STEM education.

B. Implementation

RETAIN takes place over a calendar year and includes: 1) pre-program preparation; 2) an intensive six weeks of academic research and enrichment/professional development activities; and 3) post-program workshops and onsite support to insure the successful implementation and assessment of developed teacher modules. In addition, participants will be expected to return the following year for panel sessions with newly recruited teachers, to engage in discussions with the new

cohort, and to report on the success of integrating modules into their classrooms. Fig. 1 illustrates the participant activities and how they lead to the achievement of RETAIN's goals.

1) Pre-Program Activities – Teacher Preparation:

With area high schools adopting a balanced academic calendar, the summer break for teachers can be less than 7 weeks. Pre-program activities were designed to prepare participants for their research experience and allow them to participate in lab research for the entire 6-weeks. Participants were assigned to mentors during the spring of 2015. The pre-program activities included three 20-minute visual webinars, which introduce nanotechnology concepts as well as the breadth of its applications, and one 60-minute webinar on basic scientific research skills (e.g. the scientific method, keeping a lab notebook, using library resources, accessing scientific journals, and more). Teachers were required to complete the webinars and additional readings prior to start of the summer program.

2) Research Experience and Enrichment Activities:

a) Program Orientation

Day 1 is the only day in which teachers did not participate in research lab activities. Instead, teachers attended an introductory session where they met the other participants and RETAIN mentors and staff. This session reviewed the RETAIN guidelines, the program's timeline, and expectations. Directly following this session, teachers were given a campus tour, which included common areas, library resources, labs, and shared instrumentation and available INDI resources. Following the tour, teachers attended a 2-hour general lab safety course and a 1-hour presentation on proper waste management. Upon completion, and coupled with completion of the pre-program webinar on basic research skills (e.g. the scientific method, keeping a lab notebook, and more), teachers began their mentor-led research on Day 2 of the summer program. Due to the broad range of research projects, specialized training occurred within the mentor's lab.

In figure 1, the dashed box represents the overall framework for RETAIN program initiatives. The gray box delineates and characterizes the key time periods in which cohort activities, evaluation practices, recruitment, and dissemination occur throughout a programmatic year. White boxes are program objectives. "E" represents evaluative components used to ensure program operation and that objectives are being met. The bottom row of the figure illustrates the RETAIN dissemination strategy, which, at the writing of this paper, was still in process.

b) Research Experiences:

RETAIN faculty mentors resided in different departments across campus, and while research topics vary, they shared the common goal of advancing nanomaterials research. Selected research projects focused on the design, synthesis, theory, and/or characterization of nanomaterials for

applications that span biological or sensing devices, nanoparticle theory, and renewable energy. Research activities were largely planned by each faculty mentor. Selected faculty mentors have successful track records of securing external and internal funding for their research projects.

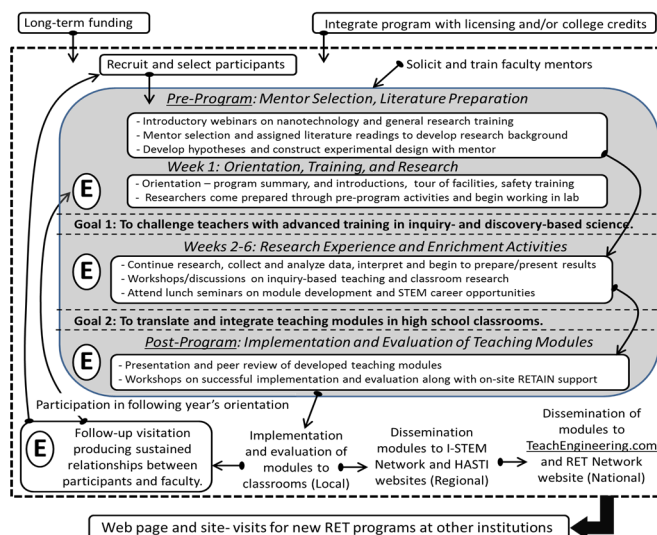


Figure 1. Organizational schematic of the RETAIN program.

c) Enrichment Activities:

During the *Research Experience* weeks, mandatory seminar and professional development activities (see Table 1) are designed to translate participants' research experiences into classroom applications through inquiry-based instruction, literature and pedagogical techniques. Integration of research projects into the classroom will be discussed throughout the program.

COURSE: INTEGRATING INQUIRY-BASED LEARNING IN THE CLASSROOM

In this brown-bag (lunch seminar) course, teachers will be educated on methods and techniques to successfully translate their summer research experiences into their classroom. Topics discussed include techniques to build critical thinking and problem solving skills in the classroom, as well as how to conduct classroom research on a small budget. Topics are aimed at producing learning modules that foster the skills needed to excel in college and future STEM careers. In addition to inspiring teachers to integrate inquiry-based learning into the classroom, the training will assist in generating ideas for the nanotechnology-related learning modules that teachers will create. This course met every Monday and Wednesday from 11:30am-1pm. It also provided teachers with three graduate credits in education.

COURSE: CAREERS IN NANOTECHNOLOGY AND OTHER STEM FIELDS

In this "brown bag" (lunch seminar) course, RETAIN participants discussed and explored careers in renewable

energy, nanomedicine, and bionanotechnology, and methods to instill students with the desire to better understand the academic and applied nature of STEM disciplines and careers. With a broad range of applications from energy, medicine, information technology, space and aeronautics, and consumer goods, teachers discussed and researched these nanotechnology content areas and developed information packets and multimedia (in the form of webpages) for learning modules aimed to give adolescents a clear understanding of the necessary skill sets, the academic requirements, and the post-secondary programs available in challenging and exciting STEM fields.

CAMPUS RESEARCH SYMPOSIUM

At the close of the summer program, participants presented their research and their ideas on how they could translate RETAIN experiences into the classroom by way of a nanotechnology-based learning module. This work was presented as a poster presentation at IUPUI's Annual Summer Research Symposium, which was open to all campus faculty and researchers. These posters presented a synthesis of their RETAIN research and course experiences and were created during the "Careers in Nanotechnology and Other STEM Fields" course.

FALL RETREAT – MODULE PRESENTATION, IMPLEMENTATION, AND EVALUATION

In the fall semester of 2015, participants convened for a one-day retreat on module implementation. At this point, participants had had several months to create nanotechnology learning modules that reflected their RETAIN experiences, engaged students, and aligned with state and national standards. Teachers constructed these modules individually with some peer collaboration during the summer courses. Each participant gave a presentation on the classroom module they had developed, and if they had implemented it already, they were requested to reflect upon this.

3) *Post-Program Activities (Fall and Spring Semesters):* Post program activities consisted of the Fall Retreat discussed above in section and a meeting in the Spring of 2016 at the state science teachers conference at which teachers presented their modules and experiences from the program. In addition, selected program alumni will be asked to return the following year for panel sessions with newly recruited teachers, to engage in discussions with the new cohort, and to report on the success of integrating modules into their classrooms.

III. ASSESSMENT OF PRELIMINARY OUTCOMES

A. Assessment Design

A convergent parallel mixed methods research design [6] was utilized for the evaluation of RETAIN. Data are in the process of being converged based upon the recent conclusion of the 2015-2016 K-12 academic school year. The qualitative

data were collected through the summer experience and during the academic year. Interviews, conversations, and observations were the primary methods utilized to collect these data. The interview protocols, located in Appendix A and C of Fore, Feldhaus, Sorge, Agarwal, and Varahramyan [7], were consistent with the protocols used in this study. These protocols focused on teacher experiences of the RETAIN program and teacher concerns over school level constraints (e.g. state standards, standardized curriculum, state and school economics, availability of materials, student attitudes and behavior, etc.) to module implementation.

Quantitative data were collected throughout the RETAIN program. Surveys were conducted to obtain participant perspectives before and after the three main stages of RETAIN (Pre-Program, Summer Experience, and Module Implementation) as well as for the entirety of the program to understand perceived contributions and experiences of the RETAIN program. Teachers were given a pre-survey, derived from a RETNetwork survey and the pre-survey used by the external evaluator, during the Orientation week. The post-survey will be given at the end of the 2015 academic year, which will mark the close of the first year of the RETAIN program. These data will not be available until after the deadlines for this conference paper. Participants also completed weekly surveys at the end of each week of the six weeks of research activities to assess the effectiveness of each faculty-participant relationship and the program itself.

As previously stated, data are in the process of being converged through ongoing conversations and data analysis between the RETAIN evaluators. By looking at points of thematic intersection within the quantitative and qualitative data evaluators hope to construct particular explanations for larger quantitative patterns as well as identify the subtle effects of RETAIN on teachers instructional practices.

B. Participants

Ten high school teachers (nine females and one male) from Indianapolis area school districts spent six weeks on the IUPUI campus involved in various areas of nanotechnology research as well as taking two courses designed around the program. Six of the teachers had five years or less of teaching experience and four of the teachers had six to ten years of previous teaching experience. Table 1 provides the ethnic/racial background of the participants.

Ethnicity/Race	Number of Teachers
Black	3
White	5
Multi-racial	2

Table 1. Ethnic/racial Background of 2015 Participating Teachers.

C. Results: Preliminary Outcomes

1) Teacher Perceptions of Courses

At the end of weeks 1 – 5 teachers were asked to take a survey related to their experience in the two courses. The

survey's had nine Likert scale questions with responses of Strongly Agree (5) to Strongly Disagree (1) along with three open ended questions of "What was most useful to you?"; "What was least useful to you"; and "What was missing?". Overall, the questions with the greatest frequency of high ratings were directly related to the instructors' knowledge and willingness to respond to questions. Weeks where teachers satisfaction was the lowest, corresponded with open ended responses relating to a desire for more time to work together in small groups. Overall, teachers were satisfied with their course experiences, with over 81% of the responses (n=43) to the question of "Overall these course meetings were effective" being agree (n=31) or strongly agree (n=4). The remaining responses (n=8) were all neither agree nor disagree.

2) Teacher Perception of Research Experience

Teachers were also asked about their experiences directly related to the research in which they were participating. As with the questions about the courses, teachers were asked Likert scale questions with responses of Strongly Agree (5) to Strongly Disagree (1). Table 2 provides that weekly average scale score for each question by week as well as the overall average for each question. The highest scoring questions directly related to the lab staff with whom the teachers worked. The lowest was related to the research content being useful. It is important to note that one of the teachers was in an area that they did not feel related directly to their teaching. This individual's response to this particular question lowered the average score.

	Week 1 (n=10)	Week 2 (n=10)	Week 3 (n=8)	Week 4 (n=10)	Week 5 (n=5)	Average
Lab work was intellectually stimulating	4.111	4	4	3.9	3.6	3.952
Expectations were clearly explained	3.333	3.9	3.75	4.2	4	3.833
Research content is useful to me	3.778	3.8	3.625	3.9	3.4	3.738
Support was readily available	4	4.1	4.25	4.4	4	4.167
Mentors were available is needed	3.444	4	4.25	4.3	4	4
Lab staff was/were knowledgeable	4.444	4.3	4.5	4.5	5	4.5
Lab staff was/were responsive to questions	4.444	4.3	4.5	4.4	4.6	4.429
This research will improve some aspect of instruction in my classroom or school	4.111	4.1	3.875	3.9	3.8	3.976
This week's research was productive	4	3.9	4	3.8	3.6	3.881

Table 2. Weekly Survey Responses for Research Experience (Question Averages).

3) Teacher Overall Program Satisfaction

Another set of questions, which were derived from the RETNetwork end of summer survey [8], focused on the teachers' satisfaction with their RET experience at IUPUI.

	Great Extent	Moderate Extent	Small Extent	Not at All
The expertise and helpfulness of the RET management in answering questions and problem solving	4	6	0	0
Your relationship with your mentor	8	0	2	0
The opportunity to participate as a member of a team	8	0	2	0
The opportunity to ask questions of the staff at IUPUI	6	4	0	0
The opportunity to interact and discuss issues with other employees at IUPUI	3	6	0	1
The availability and quality of resources, materials, and equipment	5	5	0	0
Your mentor's preparation for your arrival	4	3	1	2
Your mentor's knowledge and support of the goals of the RET	6	1	2	1
Your mentor's knowledge of the roles and responsibilities of teachers in your field	3	3	3	1
Your mentor's interest in helping you develop a plan to improve education in science, mathematics, or technology	6	1	2	1
Your mentor's commitment to providing opportunities for you to learn and gain expertise in new areas	7	1	2	0
Your mentor's ability to communicate information and expectations clearly	7	0	3	0

Table 3 provides the frequency for each response by question asked. The responses to several questions in this section can provide useful information for areas of improvement for this RET program as well as areas that were well received. Of the questions with higher satisfaction ratings in this section, two questions received eight great extents and two more received seven. Three of these four questions related to the mentors with whom the teachers worked. This will be elaborated upon in the Discussion.

Table 3. Teachers Satisfaction with the RET Experience.

4) Module Implementation

Each teacher's instructional strategies as it relates to nanotechnology varied by virtue of the freedom they had to modify their classroom curriculum. For example, one teacher took a two-week solar car activity and turned it into a two month project. In another instance, a group of teachers from the same school district were unsure of how to integrate their nanotechnology lessons into their regular classroom curriculum. Instead, they utilized a 15 minute "success period" at the start of each day to tactically implement their content. This tactic allowed these teachers to implement their nanotechnology lessons without fear of negative consequences associated with deviating from established curricular methodology by their schools. Tactic, as it is used here, is derived from the work of De Certeau [9], who describes tactics as those practices that people utilize in order to "make do" or "get by" when larger strategies constrain or limit the allowable

practices or options available. When seeking to implement PD content, teachers must negotiate a multitude of potential constraints and allowances (e.g. national and state standards, testing, school structures, political and economic interests, etc.) in order to plan the implementation of PD-derived content in their classrooms [7]. At times, constraints can be so overwhelming that the introduction of PD content takes on a tactical quality, as opposed to taking the form of a module or unit that is well-integrated into a teacher's broader curriculum map [7].

Beyond these tactics of lesson implementation, and the specific learning around nanotechnology, teachers had other "incidental learning" from the RETAIN experience. This is explored in the next section.

5) Case Study: Incidental Learning

One day during her summer research experience, a 9th grade science teacher and Project Lead the Way (PLTW) instructor, noticed a stack of papers set aside for grading on the desk of one of the lab's graduate assistants. She asked him what they were. He said that they were lab reports from undergraduates taking a course in which he was a TA. He added that the students simply don't know how to write science reports and that they are coming into university lacking basic scientific writing skills.

Based on this experience, which the teacher later said "guided [her] whole year," she decided to integrate more technical science writing into her PLTW course, Principles of Biomedical Science, which required students to write a summative report explaining the death of a young woman using evidence from a mock crime scene. To do this, she slightly revised the scientific report writing in this course to be more rigorous; for example, she required that each of her students conduct peer reviews. She was observed guiding her students as they completed peer reviews one day. During class, she stated: "You can edit your own, but you need the perspectives of others. Sometimes you are too close to the work and need other perspectives." She also repeatedly stressed the importance of the need to write objectively in the third person and support any assertions with plenty of evidence. She discouraged the use of "belief" statements. For example, she said "You shouldn't write 'I believe so-and-so murdered...' but you should say 'He murdered...'" She also encouraged them to use stock phrases, such as "evidence suggests" and "upon further analysis" in their scientific writing. In an interview following this class, she stated that she felt this assignment was a way to "better prepare" her students for the rigors of technical science writing.

This brief case study demonstrates the subtle effects RETAIN had upon participating teachers. While this specific example does not illustrate the utilization of specific nanotechnology content, it does, however, demonstrate how a teacher can benefit and change their instructional practice due to, in part, their embedment in a university research lab.

Following experiential learning theory [10][11], teachers operate and learn within an "experiential continuum" in which meaningful experiences of "growth" are reflected upon, abstracted, and applied to new experiences. RETAIN provided the teacher with the opportunity to have meaningful experiences leading to the construction of knowledge derived from "incidental learning," which is "unplanned," occurring as a "byproduct" of a core activity built around a more explicit learning objective [12][13]. While nanotechnology content knowledge and pedagogical content knowledge were the primary learning objectives of RETAIN, through the everyday laboratory experiences offered to the teacher, she was able to incidentally develop new instructional practices for scientific writing education.

D. Discussion

As a whole, teachers responded positively to their summer RETAIN experience. This is based upon their responses to the weekly surveys as well as their overall rating of the entire professional development (PD) program, where 8 of the 10 teachers rated the PD program as excellent or very good. However, there were several programmatic lessons learned that are important to consider as a means to enhance the teacher experience. Properly preparing Mentors to understand and support teacher realities and learning should be carefully planned and implemented before the teacher summer research experience commences. While several mentors in this program had previously worked with high school teachers, many were unaware of the standards around which teachers create their lessons as well as the realities that are their students, classrooms, and schools. Understanding these realities can provide a closer connection between the faculty mentors and teachers as well as allow the mentors to provide greater support to their teacher mentees in developing lessons.

However, this need could also be filled by others, beside the faculty mentor, working within the same lab as the teachers. For example, when a faculty mentor was traveling frequently, their teacher was still able to have positive lab experiences with the mentor and, overall, when there was another individual (faculty member or graduate student) with whom the teacher could engage and obtain support. Providing this support structure for teachers was also important in labs where graduate students would come in later in the morning and work late into the nights. Since teachers arrived to their labs at 8:30 am it was important for them to have knowledge of their tasks so that they could continue their projects and not feel as if their time was being misused.

Another area to consider during the teachers' summer experience was the instructional courses in which they participated. Teacher expressed areas around their course experience included:

- More time to create lessons while working in groups
- Sufficiently detailed expectations of lesson content

- More experiences with nanotechnology in the courses.

Teacher satisfaction with the courses was greatest on days in which these things were included.

Maintaining ongoing communication with teachers, before, during, and after the summer research experience were important. Making sure the initial information packet sent to teachers provide clear, concise, and thorough information about the expectations, experience, and deliverables can greatly reduce teacher anxiety and increase initial performance and overall program satisfaction. Making sure this information ties directly into the first day orientation will also help in improving the program. Maintaining this communication throughout the summer research experience is important. This provides teachers with information on who to contact with questions or concerns, and can make them feel as if their comments/suggestions have been directly addressed. When this was done, additional complications and misunderstandings were often avoided. When it was not done properly teachers satisfaction with their experience declined.

Translating teacher summer research experiences back to their classroom lessons and instructional practices is an important component of this RET program. Providing teachers with continued support when they return to their classrooms can greatly impact their overall program success [7][4]. Additionally, understanding how and what teachers are implementing is vital in measuring and understanding the greater impact of the program.

Considering the tendency for teachers to introduce tactical articulations of their RETAIN experiences, there is a need to design and provide greater scaffolding to ensure that developed modules find a proper home within the curriculum maps of RETAIN teachers, as opposed to an implementation characterized by a need to just “make do” or “get by.” With the assistance of program evaluators, the PIs have developed, and plan to implement, a new module rubric with Cohort 2 that will highlight best practices around which teachers can construct their modules, while also aiding those delivering the RETAIN professional development programming (e.g. the faculty mentors and course instructors) in the modeling of instructional practice. Since tactical expressions of the nanotechnology modules were not necessarily the goal of module implementation, this rubric should provide teachers with a greater understanding of the modules and how they will fit into established curriculum. Following the teacher reported importance of collaboration, this development strategy will also utilize teacher collaboration in the refined RETAIN courses as a means for constructing feasible nanotechnology modules. Finally, the previously presented case study points to the need to continue to explore the “incidental learning” that occurs within and through RETAIN. This case study also highlights the subtle yet, nonetheless, profound ways that RETAIN can impact teacher practice. By paying special attention to the everyday interactions and relations within RETAIN, like those

between teachers and research lab graduate students, research will continue to reveal the subtleties of learning that lie far below explicit learning goals and objectives.

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